Study on the method of identifying fractures by ant tracking technique

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Abstract. Fracture is an effective reservoir space and important seepage channel for low permeability sandstone reservoirs, which is very important for reservoir exploration and development. Conventional fracture prediction methods have high cost, slow operation speed and low resolution, which limits the promotion of fracture identification methods. Therefore, this paper proposes a fracture prediction method based on ant tracking. This method is based on post-stack seismic data. Firstly, the seismic data is denoised and the fault continuity is enhanced by using structural smoothing and variance body attributes. On this basis, the active ant tracking is used to enhance the fault boundary of the data body. Then, the data body is subjected to multiple ant tracking calculations by optimizing parameters, and finally the suitable parameter values are determined to realize the prediction of natural fractures. The results show that the technology is used to predict natural fractures, and the prediction results have high resolution and reasonable fracture distribution.

Keywords. Post-stack seismic data; ant tracking; variance body; fracture prediction.

1. Introduction

The identification and prediction of reservoir fractures is an important task for the exploration and development of fractured reservoirs, which is of great significance for the adjustment of development plans and the improvement of oil recovery. At present, the identification and prediction methods of reservoir fractures at home and abroad mainly include geological methods, logging methods, seismic methods, structural mechanics methods, dynamic analysis methods[1] and multi-information fusion methods[2]. Geological method[3] refers to the method of directly observing and describing fractures through field outcrops and cores. The fracture parameters obtained by this method are accurate, but the lateral resolution of fractures is low. The logging method can indirectly reflect the development of fractures near the well trajectory through the change of physical characteristics of fractured reservoirs[4,5], but the high cost of imaging logging, limited data and multiple solutions limit the wide application of this method. Seismic methods can detect fractures through the changes of propagation time, velocity, amplitude and frequency of seismic waves in anisotropic media in different azimuths[6], such as coherence attribute analysis technology[7,8], multi-scale edge fracture detection[9] and ant tracking[10]. Ant technology is a very popular post-stack fracture prediction technology in recent years. Compared with conventional post-stack fracture prediction technology, this method has the advantages of short running time and high prediction accuracy, and has good application effect in many areas[11-13]. The application of ant tracking technology in fracture detection in X area is discussed.

2. Basic Principle of Ant Tracking Technology

Ant technology, also known as automatic fracture tracking technology, is a seismic attribute based on ant colony algorithm developed by Schlumberger. The ant colony algorithm was first proposed by Dorigo M et al.[14] as a stochastic optimization algorithm. The algorithm follows the principle that ants use pheromones that attract ants to convey information between their nests and food sources to find the shortest path. Set a large number of such ' ants ' in the seismic data volume and let each ' ant ' move forward along the possible fault plane and release pheromones to track the fault plane through the path of the ant 's forward movement. The essence is to track according to the difference between amplitude and phase in the seismic data, that is, the characteristics of discontinuity in the data volume, move forward along possible fault planes and fractures, and search for fault traces until they are fully characterized.

3. Technical process

3.1 Seismic data preprocessing

Before the ant tracking, the seismic data volume of the same set of SEGY format is first analyzed, and its thinning processing is converted into a sparse data volume with small memory space and clearer plane structure. Therefore, for the study area, the selection of sparse data volume for subsequent ant tracking construction can greatly improve the operation speed, and effectively save the time of parameter test, comparison and section and slice retrieval. After the thinning process, we first perform structural smoothing on the thinned data volume. Compared with the original seismic profile before structural smoothing, the seismic profile after structural smoothing has clearer in-phase axis dislocation and more vertical faults (Figure 1, the red arrow in the figure indicates the in-phase axis dislocation area). The volume noise of seismic data is suppressed and the continuity of seismic events is enhanced after structural smoothing. At the same time, due to the smoothing effect of the fault boundary, the corresponding seismic signal becomes enhanced and smoothed.

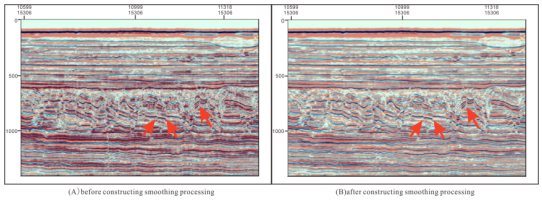

Fig. 1 Seismic section comparison before and after structural smoothing, the red arrow in the figure indicates the in-phase axis dislocation area

3.2 Variance system

The basis of ant body is to detect the discontinuity of seismic data. The common effective attribute bodies are variance body and chaos body. For the seismic data in this area, the variance attribute characterizes the fault better, so it is selected as the basic attribute of ant tracking. The variance attributes are extracted from the preprocessed data volume, and the variance body (Figure 2) is obtained. It can be seen that the quality of the variance body is obviously improved, the local fault relationship is clear, and the interference of noise and non-fault factors is effectively weakened.

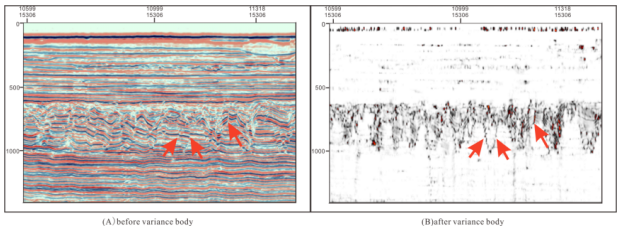

Fig. 2 Comparison of seismic sections before and after variance body, the red arrow in the figure indicates the in-phase axis dislocation area

3.3 Ant body tracking

1. Key parameter

Ant tracking properties controlled by the tracking parameters, the algorithm mainly includes 6 parameters, parameters meaning and characteristics are shown in Table 1.

Table. 1 Parameter Setting and Meaning of Ant Tracking Method

parameter	meaning	characteristic
Initial ant boundary	define the initial distribution range of ants	the smaller the parameter, the easier it is to identify small scale faults
tracking deviation	set the deviation range of ant searchable direction	the larger the parameter, the better the identification of bending fault
step size in search	step length of each ant search	the larger the parameter, the greater the search capability, but some details may be ignored
Illegal step	allow search beyond defined step size	the larger the parameter, the more continuous
Legal step	number of legal steps that must be included in the search path	the smaller the parameter, the more limited and discontinuous the fracture search
Search threshold value	percentage of illegal steps allowed during tracking	the larger the parameter, the stronger the search capability

Tracking parameter effect comparison

Firstly, the “passive” ant tracking method is selected to track the above variance body for the first time. The passive ant tracking algorithm is “lazy ant”, which tends to track extremely strong signals and abandon weak signals, so it helps to suppress noise and reflect the trend of large faults (Fig.3). The specific parameters are : initial boundary is 7, tracking deviation is 2, step size in search is 3, Illegal step is 1, Legal step is 3, Search threshold value is 5%. Thus an edge - enhanced ant tracking attribute data body is obtained.

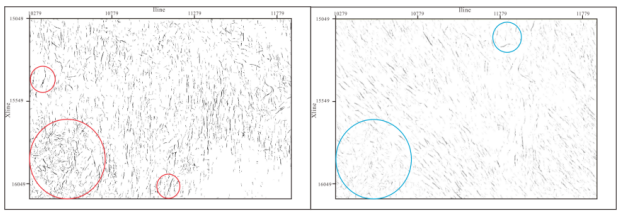

Fig. 3 First ant tracking, red and blue areas depict contrast areas for fractures.

A second ant tracking is performed based on the first ant tracking data body described above. Petrel was used to conduct multiple tests on the secondary ant tracking parameters to determine the optimal parameter values suitable for the study area. The ant parameters in Fig. 4 are: initial boundary is 5, tracking deviation is 3, step size in search is 3, Illegal step is 3, Legal step is 1, Search threshold value is 10%. Compared with the first ant body, the parameter ant body is more detailed in fracture characterization and effectively reduces noise interference. Among them, Figure 4 (a) in the red circle range and 5 (b) in the red circle range compared to Figure 3 (a) (b) fracture characterization more clearly, but the parameter to identify more discontinuous points, to maximize the prediction of the location of discontinuous points, used to predict the fracture resolution is too low, the fracture is more fragmented.

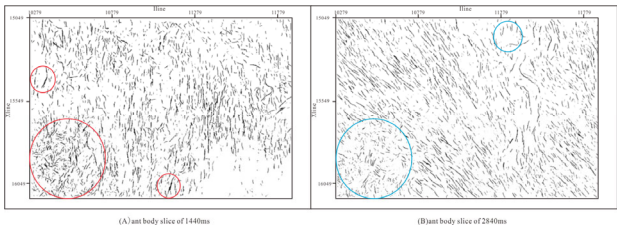

Fig. 4 First ant tracking, the tracking parameter is 5333110,red and blue areas depict contrast areas for fractures.

In order to obtain high-definition ants, we continue to optimize the extraction parameters of ants. The parameters of ants in Figure 5 are as follows: initial boundary is 4, tracking deviation is 2, step size in search is 3, Illegal step is 1, Legal step is 3, Search threshold value is 5%. Compared with the ant body with the parameter of 5333110, the ant body with this parameter is more accurate in identifying fractures, but the micro is not detailed enough and the resolution between fractures is not clear.

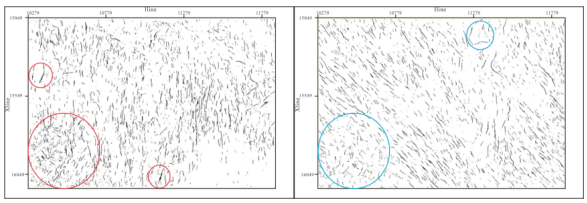

Fig. 5 First ant tracking, the tracking parameter is 423135, red and blue areas depict contrast areas for fractures.

In order to improve the accuracy of local microscopic prediction, initial boundary is 5, tracking deviation is 2, step size in search is 3, Illegal step is 1, Legal step is 3, Search threshold value is 5%. The horizontal slices of the ant body for the parameters are observed and analyzed, as shown in Fig.6. It can be seen that the parameters describe the fractures in detail and can see the direction of a single fracture.

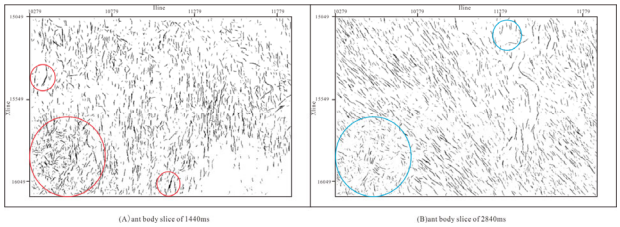

Fig. 6 First ant tracking, the tracking parameter is 523135, red and blue areas depict contrast areas for fractures.

4. Application effect analysis

The fracture characteristics of three structural zones A, B and C in X layer of the study area are statistically analyzed. Among them, A represents the diapir development zone, B represents the diapir eaffected zone, and C represents the diapir slope zone. The statistical results are shown in Fig.8, the east of the diapir is dominated by NW-trending fractures, and the fracture density tends to decrease away from the diapir area, which is consistent with the geological law.

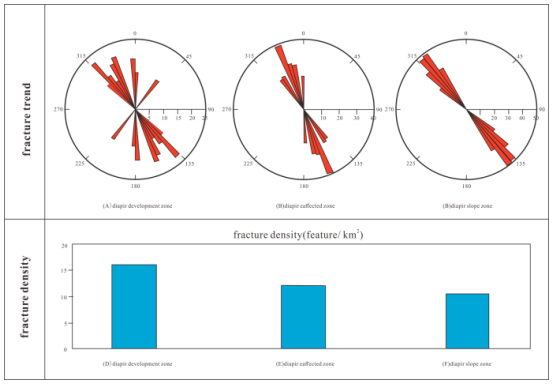

Fig. 7 Fracture statistical diagram

5. Summary and conclusions

Ant tracking data volume can show the development of small structures more intuitively and quickly. Through the study of fracture prediction in a certain area, the following conclusions can be drawn :

(1) Ant tracking algorithm can eliminate the subjective factors of interpreters, making the interpretation results of small faults more objective.

(2) Ant tracking is an advanced technology of post-stack fracture prediction based on ant colony algorithm. Before ant tracking, it is necessary to filter the original seismic data to improve the signal-to-noise ratio of seismic data and provide high-quality data for post-stack attribute extraction.

(3) Through the statistics of fracture development characteristics, the reliability of fracture prediction results is confirmed, which provides an important basis for the next oil and gas prediction.

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